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The Meiofaunal Assemblages of Rocky Shore Site in the Taklong Island National Marine Reserve, Southern Guimaras, West Central Philippines

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Owing to their small size and difficult taxonomic identification, meiofauna are often neglected as part of the benthic ecosystem. Most of the studies done on meiofauna have been limited to soft bottom intertidal or subtidal areas and very few were done on rocky shores. This study was done to characterize the meiofaunal assemblages of a rocky shore site in Southern Guimaras, west central Philippines as part of a long-term sampling program. Following the Natural Geography in Shore Areas (NaGISA) sampling protocol, four transects (3 intertidal and 1 subtidal), along the depth gradient of high tide (HT), mid-tide (MT), low tide (LT), and 1 m subtidal (ST), with 5 replicates each, were laid parallel to the shore of the mainland. Meiofaunal assemblages were sampled in August 2011 and October 2012. The percentages of macroalgal cover and biomass were also calculated. Predominating taxa in both surveys were quite consistent, i.e., harpacticoids, nematodes, syllid polychaetes and tanaid crustaceans. Except for the nematodes and chironomids, densities of the remaining dominant taxa (harpacticoids, crustaceans, and polychaetes) generally increased with depth, and showed a strong correlation with macroalgal biomass, further reflecting the depth-correlated higher availability of microhabitats and shelter from predators, as well as the decrease in the negative effects of hydrodynamic forces. Overall mean annual densities (2.1 ± 1.9 ind. cm^{-2}) from the site proved to be lower compared with those in reported studies conducted in other rocky shore and intertidal habitats.

Key Words: meiofauna, NaGISA, rocky shore, tidal influence, Guimaras, Philippines

Abbreviations: HT – high-tide transect, LT – low tide, MT – mid-tide, NaGISA – Natural Geography in Shore Areas, ST – subtidal, THT – high-tide transect, TINMAR – Taklong Island National Marine Reserve, TLT – low tide transect, TMT – mid-tide transect, TST – 1 m subtidal transect

INTRODUCTION

Distribution patterns of organisms in various types of habitat provide not only insights into their interactions and community organization but also into the conditions of various habitats such as seagrass beds, mangroves, and rocky shores (De Troch et al. 2008). Rocky shores are high-energy habitats exposed to wind-driven waves, alternating currents, extreme temperatures and salinity. These habitats support a wide array of organisms but only primarily those which are able to adapt to these highly fluctuating environments (Denny and Gaines 2007; Little et al. 2010). In these types of environment where harsh conditions often prevail, organisms tend to develop positive interactions in order to ameliorate the effect of primary stressors (i.e., high wave action, tidal change and predation) (Bertness and Callaway 1994). The organisms that are able to survive to regular transition of tides include not only attached vegetation such as algae, but also mobile organisms such as fish and crustaceans, sessile and sedentary invertebrates, which are mainly classified as epifaunal assemblages belonging to the macro- and meiofauna.

Meiobenthos are small benthic and interstitial organisms that pass through a 500 (1000) µm sieve and are retained on a 44 µm (or 63, 31 µm) sieve (Giere 2009). Nematodes are generally the most abundant taxon of meiobenthos (often > 50% of total abundance) followed by harpacticoid copepod as co-dominant taxon (Balsamo et al. 2010). Ecologically, meiofauna are important components of a detrital trophic complex, serving as a link between organic detritus and higher trophic levels (Albertelli et al. 1999). Besides playing an important role in benthic food webs as consumers (feeding on detritus, diatoms and algae, and preying on other small metazoans; Pasotti et al. 2012; Buffan-Dubau and Carman 2000), meiofauna also serve as producers (being a food source for macrofauna and fish; Schückel et al. 2013; Carpentier et al. 2014). Meiofauna are also known to facilitate biomineralization, and are useful indicators in pollution research (Balsamo et al. 2010). They are known to exist in high diversity and abundance, with direct development and short generation time, thus making them suitable for monitoring studies (Kennedy and Jacoby 1999).

A growing interest in the diversity and distribution patterns of animals on rocky shores has been observed through the years (Underwood 2000). Unfortunately, there is no known study on the distribution of the rocky shore meiofauna in the Philippines, with the exception of the study made by del Norte-Campos et al. (2010) on rocky shore macrofauna. Most studies on the benthos, including those on the meiofauna (Mequila et al. 2004; Burgos 2009; Burgos et al. 2013) have been conducted on soft (Palla et al. 2013) and/or vegetated (del Norte-Campos and Burgos 2015) bottoms. Knowledge on how meiofauna are influenced by tidal levels on rocky shores has to date been neglected in the country.

This study thus generally aims to characterize the meiofaunal assemblages on a rocky shore NaGISA site in the Taklong Island National Marine Reserve Guimaras in 2011 and 2012. Specifically, it aims to determine meiofauna taxa group abundance and composition, and compare these with tidal levels, algal cover and biomass in two surveys (August 2011 and October 2012).

MATERIALS AND METHODS

The Taklong Island National Marine Reserve (TINMAR) is a marine-protected area (Campos et al. 2002) established in 1990. It is located between latitudes 122˚29′-122˚31′ E and longitudes 10˚24′-10˚26′ N on the southwestern tip of Guimaras Island (Fig. 1). Following the NaGISA sampling protocol (Rigby et al. 2007), the sampling in a rocky shore area in TINMAR (Fig. 2) was conducted in August 2011

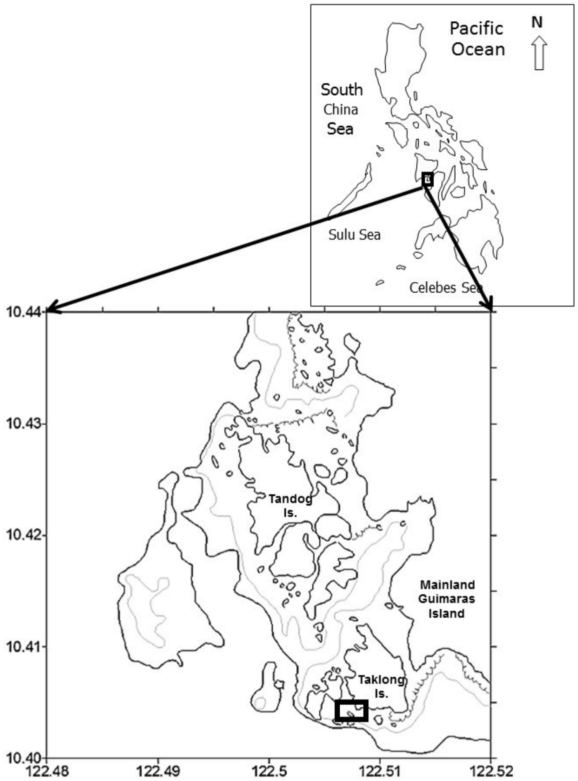

Fig. 1. Location of the study area in the Taklong Island National Marine Reserve (TINMAR), Southern Guimaras, west central Philippines.

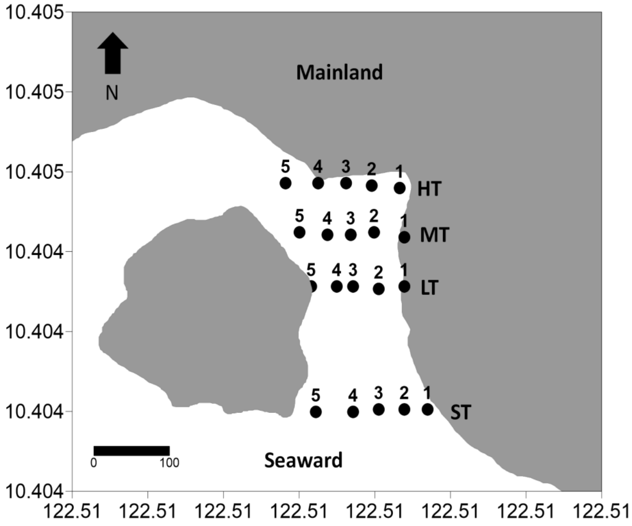

Fig. 2. Sampling stations in the rocky shore area at the Taklong Island National Marine Reserve (TINMAR), following the NaGISA protocol, consisting of four transects: **HT** – high tide transect, **MT** – mid-tide transect, **LT** – low tide transect, and **ST** – 1 m subtidal, each with five sampling points.

and October 2012. NaGISA is a global program which aims to monitor long-term biodiversity of organisms all over the world.

Placement of transects followed that of del Norte-Campos et al. (2010), i.e., four sampling transects were laid parallel to the shore of the mainland, three in the *intertidal*: HT (High Tide zone), MT (Mid-tide zone), LT (Low Tide zone), and one in the *subtidal* zone: ST (1 m depth) (Fig. 2). Each transect was 27 m in length, corresponding to the maximum expanse of the rocky shore. Five replicates at 2, 7, 12 17 and 22 m that were 5 m apart from each other were sampled at each transect. In every replicate, a 1 m^2 quadrat was laid wherein % macroalgae cover was taken. From this 1 m^2 area, algae found within a 50 x 50 cm (2,500 cm^2) quadrat were removed for identification and wet weight determination. In each of the 2,500 cm^2 quadrats, a 25 x 25 cm quadrat was laid wherein all organisms were harvested, and then preserved in 10% formalin solution with Rose Bengal stain. Collected samples were washed over stacked sieves (500 and 63 μm mesh) in the laboratory as prescribed in the NaGISA sampling protocol (Rigby et al. 2007). Material retained in the latter mesh was sorted in the laboratory into the different taxa using a dissecting microscope.

Densities (ind. cm^{-2}) of meiofauna were computed. Algal cover (%) and biomass (g m^{-2}) were likewise calculated, the latter as the wet weight of algae divided by the total area where it was collected. Correlation analysis using Pearson coefficient was carried out to determine the nature and degree of interaction between the meiofauna and habitat parameters such as algal biomass and cover. Two-way analysis of variance (ANOVA) was used to examine temporal (between surveys) variations in meiofaunal abundance.

RESULTS

Meiofaunal Abundance and Taxa Composition

The overall mean density of meiofauna in TINMAR for both years was 2.10 ind. cm^{-2} (SD = 1.90 ind. cm^{-2}) (Table 1), showing a sharp increase from 0.76 ind. cm^{-2} in 2011 to 3.45 ind. cm^{-2} in 2012 (Table 1). The major taxa recorded were harpacticoids (33.6%), nematodes (30.2%), other crustaceans (18.7%), polychaetes (10.5 %), and chironomids (2.2%). These groups constituted 95.2% of the total sample while the remaining 4.8% was composed of groups such as chelicerates (pycnogonids and halacarids), turbellarians, gastropods, and bivalves (Table 1).

Spatial Distribution of Meiofauna

Meiofaunal densities varied between years and tidal levels with relatively higher densities were observed in October 2012 (Fig. 3). Of the four tidal levels, the subtidal transect (ST) showed the highest densities with mean values of 4.97 ind. cm^{-2} in October 2012 and 0.96 ind. cm^{-2} in August 2011. The lowest densities, on the other hand, were observed in the high-tide transect (HT) in August 2011 (0.50 ind. cm^{-2}) and in the low-tide transect (LT) in October 2012 (2.16 ind. cm^{-2}). The spatial distribution of meiofauna also showed a subtle increase with depth except for the low-tide transect (LT) especially in October 2012 wherein only a slight deviation was observed. Two-way ANOVA showed significant differences in the meiofaunal densities between surveys ($F = 77$, $p = 0.019$) with highest abundance in October 2012 and between tidal levels ($F = 4.3$, $p = 0.013$) with significant differences observed between the subtidal and the low-tide transect (Tukey HSD). There was also a significant interaction between year and tidal levels ($F = 4.1$, $p = 0.015$). The overall meiofaunal density was significantly correlated with algal biomass ($R = 0.959$, $p < 0.05$) and weakly correlated with algal cover ($R = 0.188$, $p > 0.05$). Algal biomass for all the tidal zones was higher in October 2012 compared with August 2011 whereas algal cover was higher in August 2011 (Fig. 5).

Densities of the different meiofaunal groups also varied across tidal levels (Fig. 4). The most dominant groups such as nematodes and harpacticoid copepods exhibited opposite trends of spatial distribution. Nematode densities decreased with depth (tidal level) while harpacticoid densities increased with depth. Harpacticoid densities also followed an increasing trend with algal biomass. Pearson correlation showed a significant positive correlation between algal biomass and harpacticoids ($R = 0.997$, $p < 0.05$). A positive (although insignificant) correlation was observed with algal cover ($R = 0.183$, $p > 0.05$). Meanwhile, nematode densities were inversely correlated with algal biomass ($R = -0.488$, $p > 0.05$) but positively (although insignificantly) correlated with algal cover ($R = 0.345$, $p > 0.05$).

Table 1. Mean density (ind. cm^{-2}) and relative abundance (%) of the top ten meiofaunal groups collected from the rocky shore site in the study area.

Major Group	22-Aug-11	18-Oct-12	Mean Density (ind. cm^{-2})	Relative Abundance (%)
Harpacticoid	0.36	1.06	0.71	33.6
Nematode	0.02	1.25	0.63	30.2
Crustacean	0.26	0.53	0.39	18.7
Polychaete	0.05	0.39	0.22	10.4
Chironomidae	0.02	0.08	0.05	2.2
Chelicerates	0.00	0.07	0.04	1.7
Turbellaria	0.02	0.03	0.03	1.3
Gastropoda	0.01	0.02	0.02	0.8
Bivalve	0.00	0.02	0.01	0.5
Fish egg	0.00	0.00	0.00	0.1
Others	0.01	0.01	0.01	0.5
Overall mean density	0.76	3.45	2.1	100

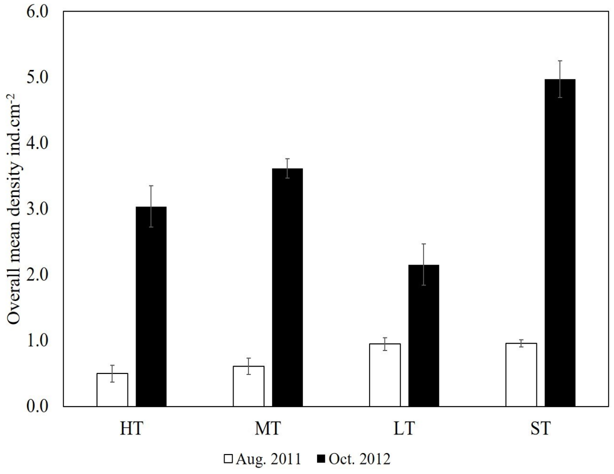

Fig. 3. Overall mean meiofaunal densities (ind. m^{-2}) from different tidal levels (**THT** – high tide transect, **TMT** – mid-tide transect; **TLT** – low tide transect, and **TST** – 1 m subtidal) at the study area in both surveys.

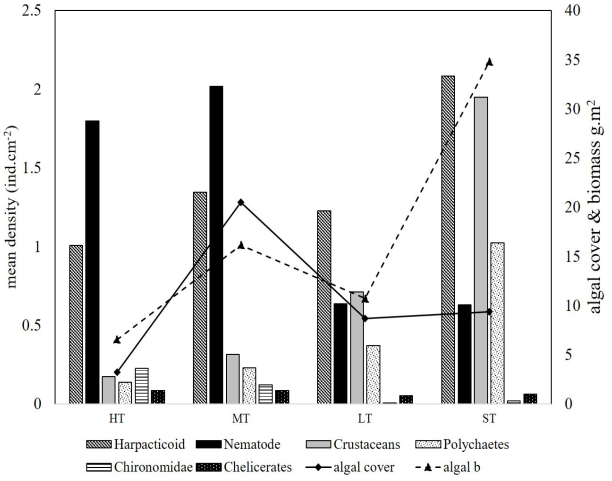

Fig. 4. Abundance (ind. m^{-2}) of the dominant meiofaunal groups in algal cover (%) and algal biomass (g. m^{-2}) on the rocky shore at the study area.

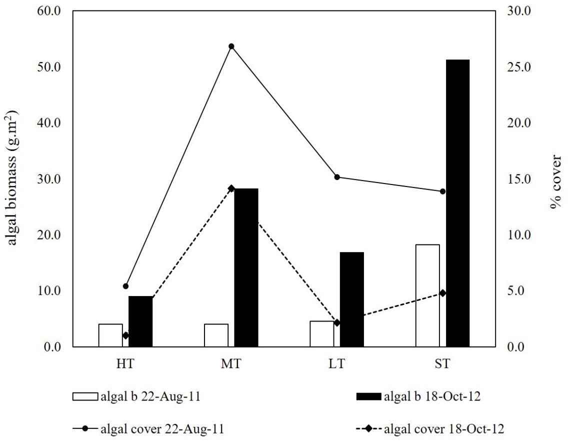

Fig. 5. Comparison of algal cover (%) and algal biomass (g. m^{-2}) between surveyed years on the rocky shore at the study area.

Densities of both crustaceans (others except harpacticoids) and polychaetes, mainly Syllidae and Capitellidae, also increased with depth as well as increasing algal biomass (Fig. 4). Both crustaceans and polychaetes showed strong positive correlation with algal biomass (crustaceans R = 0.926, polychaetes R = 0.945; $p > 0.05$) and negative (although insignificant) correlation with algal cover (crustaceans R = –0.083, polychaetes R = –0.053; $p > 0.05$).

Chironomids and chelicerates (pycnogonids and halacarids) showed a decreasing pattern in abundance with respect to depth, which was very evident with the former group (Fig. 4). Chironomids were negatively correlated with both algal cover (R = –0.195; $p > 0.05$) and algal biomass (R = –0.566; $p > 0.05$), while chelicerates were inversely correlated with algal biomass (R= –0.296; $p > 0.05$) and positively correlated with algal cover (R = 0.267; $p > 0.05$).

DISCUSSION

The overall mean density of meiofauna in this study was lower than the previously reported range of densities from other areas, including those from TINMAR, Guimaras (Table 2). This result could be due to the fact that hard substrates like the rocky shores often lack interstitial spaces compared with soft bottom, so meiofauna have reduced possibility of colonization. Moreover, rocky shores do not typically provide the rich food supply from the microphytobenthos coming from the high organic matter in adjacent seagrass beds, or the rich detritus from mangrove areas. Lush vegetation and the high nutrient flux in the latter habitats render higher productivity rates (Chinnadurai and Fernando 2007; Giere 2009). In addition, the very low density of meiofauna recorded in this study compared with other rocky shore studies could also be due to the sampling methods used. Danovaro and Fraschetti (2002) and Fraschetti et al. (2006) both used corer to sample the sediment which might have yielded more organisms compared with scraping the surface of the substrate. Lack of technique standardization used especially for rocky shores often renders difficulty in comparing quantitative studies (Danovaro and Fraschetti 2002).

Although the overall abundance of meiofauna in this study is lower compared with the results of other studies, the densities generally increased with depth (Fig. 3). Rocky shores, in general, are affected by strong currents and extreme wave action that transport large particles across the intertidal zone, adversely affecting benthic organisms (Knox 2000; Little et al. 2010). The steep environmental gradients in hard strata also expose the organisms to a wide range of temporal and spatial natural fluctuations unlike those of soft substratum and deeper subtidal areas where conditions are more stable (Boaden 1985; Thompson et al. 2002). The more sheltered subtidal portion of the study area also promotes proliferation of the biomass of algae. This trend of increasing density with depth and algal biomass (Fig. 4) was shown by harpacticoids whose numbers increased with increasing micro-spatial habitat complexity such as those found in phytal environments (Zaleha et al. 2010). The same pattern of distribution was observed in tanaids, cumaceans and gammarid amphipods. High algal biomass equates to highly branched and higher algal assemblages, represented here by the dominance of *Padina*, *Sargassum* and *Turbinaria* in the deeper portion (ST) of the study area. The canopy and microhabitats generated by the macroalgae provide refuge for the mobile crustaceans from predation (Guerra-Garcia et al. 2010). Moreover, the robust algal branched and wide leaves could also minimize the turbulence as an effect of wave force, thus promoting a more stable environment for the organisms.

The higher algal biomass observed in the subtidal area, despite the same pattern of macroalgal coverage, could be due to the change in algal assemblage present compared with other tidal zones. Certain species of algae would have a more horizontal growth, which means higher coverage, but other species tend to grow vertically, thus generating low coverage but with high biomass. The best example of algal genus showing such a characteristic is *Sargassum* which was observed to be abundant in the study area. This type of algal species tends to be more complex in structure and to have larger fronds compared with simpler and smaller algal species. In general, the more complex the algal frond, the larger the available surface for colonization by meiofauna (Danovaro and Fraschetti 2002; Hull 1997; Gee and Warwick 1994a, 1994b), macroepifauna and epiphytic algae. Temporally, the significant differences in meiofauna distribution

Table 2. Meiofaunal densities (ind. cm^{-2}) from worldwide studies conducted in rocky shores and intertidal areas.

Area	Density (ind. cm^{-2})	Bottom Type	Literature
TINMAR, Guimaras, Philippines	2.1	Rocky shore	This study
TINMAR, Guimaras, Philippines	8.02	Intertidal	Burgos (2009)
Concepcion Iloilo, Philippines	18.5	Intertidal	Nillasca (2013)
Middle Adriatic Sea	119.33	Rocky shore	Danovaro and Fraschetti (2002)
Apulian coast, Italy	16.8–39.5*	Rocky shore	Fraschetti et al. (2006)
False Bay, South Africa	77.0–79.0*	Rocky shore	Gibbons and Griffiths (1986)
Goa, India	38.6	Intertidal beach	Ingole and Parulekar (1998)
Rio de Janeiro, Brazil	115.6–1312.5	Sandy beach	Albuquerque et al. (2007)

*Reported in range
TINMAR – Taklong Island National Marine Reserve

between years might also be partly due to the difference between algal biomass which was three-fold higher in October 2012 compared with August 2011.

Syllid polychaetes are low motile organisms and are intolerant of high-stress severe environment conditions such as high wave exposure, degree of immersion, thermal conditions, and hence they seek shelter to avoid harsh environments (Serrano et al. 2006). Their low tolerance for desiccation was thus reflected in the positive relationship of their densities with depth (Fig. 4). A previous study by del Norte-Campos et al. (2010), which was conducted on the same rocky shore site, allows a comparison between the macrofauna and the meiofauna. That is, while diversity of organisms was highest for both in the TST, signifying the importance of the lesser degree of exposure to the number of organisms, trends in density with depth and the correlation of abundances to algal cover and biomass differed between macro- and meiofauna, thereby suggesting that the two benthic groups respond differently in rocky shores.

In the present study, opposite trends were observed in nematodes, chelicerates (pycnogonids and halacarid) and chironomid abundances which were higher in the more exposed intertidal sites (THT and TMT), and decreasing in the low intertidal (TLT) and subtidal (TST) areas (Fig. 4). Nematodes usually dominate in areas with finer sediment (Riera et al. 2014; Semprucci et al. 2010; Urban-Malinga et al. 2005), and this explains their highest abundance in the high-tide transect (THT) where deposition of fine sediment during the high tide is more predominant. Chironomidae, on the other hand, is the most widely distributed and frequently the most abundant group of insects in freshwater and terrestrial habitats, although they are sometimes found in the marine environment especially in intertidal areas. Their high abundance may be explained by water run-offs from the mainland that drain into the rocky shore area. Although they are known to be highly adapted to a wide gradient range of different environmental factors such as salinity, oxygen concentration, and pH, among others (Armitage et al. 1995), chironomid species are most abundant in higher shores because of their inability to tolerate prolonged immersion (Danovaro and Fraschetti 2002). The rocky substrates in higher shores provide crevices for protection, sources of attachment and food beneficial for constructing larval body cases (Fraschetti et al. 2006).

CONCLUSION

Temporal and spatial distributions of meiofauna were more affected by habitat complexity which was represented by both algal biomass and algal cover. Abundance of most meiofauna taxa generally increases with increasing algal biomass across different tidal levels with highest mean values recorded from the subtidal areas. Despite the absence of species-specific quantification of macroalgae, it is clear that the type of algal assemblage would affect meiofaunal distribution differently.

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